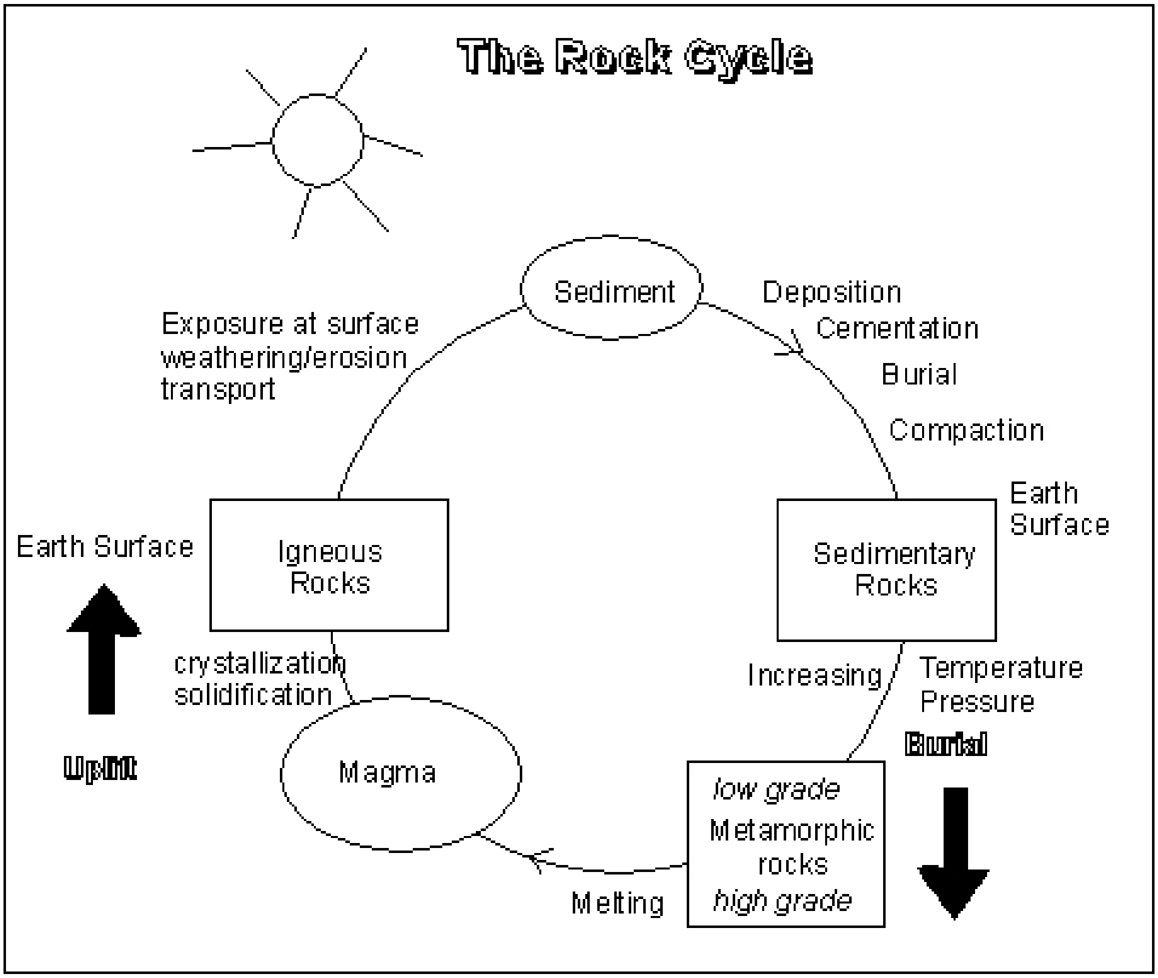
Introduction

Throughout the lecture portion of this course, we will see that there are definite relationships among the major types of rocks: **IGNEOUS** (formed from a melt), **SEDIMENTARY** (formed by surface processes), and **METAMORPHIC** (changed by heat and pressure). Through any number of processes, acting over geologic time, any one rock-type can be changed into one of the other types. These relationships form the **ROCK CYCLE**. This cycle is a simple way of showing the relationships among rock families, and the intermediate products and processes involved in changing rocks, as well as the shape and composition of the earth's surface.



Melting

At one time the surface of the earth probably was entirely molten. Therefore it can be said that all crystal materials were ultimately derived from ***magma*** (molten rock). For this reason, discussion of the rock cycle begins with the cooling of magma. As liquids are cooled, they begin to form a solid, with the temperature of solidification depending on the composition of the liquid. Magma begins to solidify at between ~800-1200 ºC, depending on the exact composition and conditions of cooling (e.g. water content, pressure, etc). This cooling usually produces mineral grains (crystals) and is therefore called ***crystallization***.

Magma that flows out onto the earth's surface (***lava***) cools very rapidly to form rocks with small (microscopic) crystals or a glass (non-crystalline). These rapidly cooled rocks are called ***volcanic igneous rocks*** (*Vulcan = Greek God of Fire*). If magma does not reach the earth's surface, but cools and solidifies in the upper reaches of the crust, we call the result a ***plutonic igneous rock*** (*Pluto = Greek God of the*

Underworld). The rock layers surrounding and overlying plutonic rocks act as an insulating blanket, causing this type of rock to cool and solidify very slowly. This allows crystals in plutonic rocks to grow much larger than their volcanic counterparts, and it is not unusual for plutonic rocks to consist entirely of large (megascopic) crystals.

Weathering

When rocks are exposed at the earth's surface (by volcanism, uplift of mountains, etc) they are placed in an environment that is inherently different than the environment in which they formed, or in which they were derived. Consequently, rocks exposed at the earth's surface begin to break down under a process called ***weathering***. Weathering can be classified in two broad categories. ***Mechanical weathering*** is the physical breakdown of rocks (i.e. breaking of big rocks into little rocks). This may happen through rock fall, landslides, wedging & cracking by tree roots, water freezing and expanding, etc. ***Chemical weathering*** is the chemical breakdown of minerals (the primary constituents of rocks) to form minerals that are more stable on the earth's surface. For example, metallic iron, when exposed to air and water, will change to rust, a substance of quite a different chemistry (a combination of oxygen, iron and water).

Erosion & transport
As weather breaks rocks down, they are eventually removed from their place of origin by ***erosion***. The weathered material (sediment), can be transported by:

1. **Water** - In the form of rivers & streams, wave action on the beach, ocean currents, etc
2. **Air** - As wind blows dust, sand, etc.
3. **Ice** - Flowing down slope as glaciers
4. **Mass Movement** - Simply the down slope movement of material driven by it's own weight (e.g. landslides, mudflows, etc).

Sediment includes things like sand, gravel and clay, as well as bones, shells, and other organically-derived remains.

Deposition & lithification
Transported sediment is eventually deposited at some location, called the ***depositional environment***. Sand dunes, beaches, river floodplains, lake bottoms and gravel bars are all examples of specific sedimentary environments. As sediment is buried deeper and deeper under newer sediment, it begins to undergo compaction, and eventually solidifies, forming a true sedimentary rock. Solidification of a sedimentary rock is called ***lithification***, and most commonly occurs through a process of ***cementation***, caused by precipitation of minerals between the sediment particles, which binds the rock together. Any material within a sedimentary rock that is an indication of past life is called a ***fossil***; nearly all fossils occur in sedimentary rocks.

Metamorphism
If burial of rock continues to greater depths, the rock becomes subjected to increasingly high temperatures and pressures. Very often, these conditions cause the mineralogical composition of the rock to change through solid-state recrystallization. This process is called ***metamorphism***, and produces metamorphic rock. These "changed rocks" which have been effected by relatively low pressures and temperatures are ***low-grade*** metamorphic rocks, while the most strongly altered metamorphic rocks are ***high-grade*** metamorphic rocks. Very often high-grade metamorphic rocks show evidence of flowage or partial melting, attesting to the extreme geologic conditions they have experienced.

Completing the cycle
When rocks are exposed to extremely high temperatures, they eventually melt and form magma, thus completing the rock cycle. There are several ways in which the complete rock cycle can be interrupted, however. For example, a metamorphic rock may be uplifted and eroded, without ever melting to form an igneous rock. Other "shortcuts" are also possible.

Procedure

Study the diagram of the rock cycle that follows. Make sure you understand the relationships illustrated on the diagram, and described in the introduction above.

The questions that follow are keyed to the rock and sediment samples available in the lab. They are designed to get you started in observing rocks and minerals, and thinking about the relationship between different kinds of rocks. Please be as accurate and complete in your descriptions as possible. Use a quick sketch where appropriate and explain yourself fully.

Questions

1. **Igneous Rocks** - Igneous rocks, formed by crystallization of magma, consist of either glass (if cooled quickly) or interlocking mineral grains (if cooled more slowly). We will first look at some **VOLCANIC** igneous rocks, which formed at the earth's surface.

   SAMPLE #1 - Basalt
   What evidence suggests this rock was once molten? ***(1 pt)***

   What might be the origin of the spherical holes (called vesicles) in this rock? ***(2 pts)***

   SAMPLE #2 - Basalt
   Is there any evidence that this rock may have been molten at one time? ***(1 pt)***

   Can you see any mineral grains in this rock (use your hand lens or a microscope)?. If so, sketch or describe them as best you can. ***(2 pts)***

   SAMPLE #3 - Obsidian
   Can you see any mineral grains in this rock?___________ Explain what you see (or don't see) that indicates this sample is a glass. ***(3 pts)***

   List at least 2 important differences in appearance between this rock and sample #2. ***(4 pts)***

   SAMPLE #4 - Pumice
   This is one of only a few rocks that will float. Why is this rock so lightweight? ***(2 pts)***

Look at this sample carefully under the microscope. Sketch the texture you see. Is this rock a glass? ***(2 pts)***

PLUTONIC igneous rocks form within the earth's crust, where they cool at a much slower rate than volcanic igneous rocks. This slow rate of cooling give the mineral grains a much longer time to grow.

SAMPLE #5 - Quartz Diorite
Can you see any mineral grains in this rock?_________How many different types of minerals can you observe?____________Briefly describe each carefully, noting its color and whether or not it has CLEAVAGE. (Note that not all the dark minerals are the same, nor are all the light ones….)***(6 pts)***

Do you see any material between the mineral grains (i.e. matrix or cement), or are the grains tightly interlocking? ***(2 pts)***

Do you think this rock cooled faster or slower than rock #2? Why? ***(3 pts)***

SAMPLE #6 - Biotite Granite
What observation can you make about the SIZE of the grains in this rock? ***(2 pts)***

Which mineral in this rock probably began to form first as the magma started to cool? ***(3 pts)***

SAMPLE #7 - Igneous Dike
A dike is a tabular igneous rock body that forms when magma intrudes into a fracture and solidifies. Is the dike (light colored) rock OLDER or YOUNGER than the dark colored rock? Explain how you know this. ***(4 pts)***

II. Weathering – Both mechanical and chemical weathering effects all rocks exposed at the earth's surface. In this lab, we will look at the weathering of some plutonic igneous rocks.

SAMPLE #8 – Quartz Diorite
How is the chemically weathered surface of this rock different from the fresh surface? (Note the difference in the black, flaky mineral and the white mineral with cleavage.) **_(4 pts)_**

SAMPLE #9 – Exfoliation Slab
Expansion has caused this rock to break off in plates or slabs parallel to the weathered surface. This process is called exfoliation. Can you tell which surface of the slab was exposed to the air, and which was underneath? How? **_(4 pts)_**

SAMPLE #10 – Gruess
Mechanical breakdown of plutonic igneous rocks, aided by chemical weathering, produces granular material called GREUSS. This material comes from the same rock as samples # 5 and #8. Can you see all of the same minerals here as you saw in the two previous specimens? How does the black, flaky mineral in the gruess differ from the same mineral in the fresh rock samples? **_(2 pts)_**

SAMPLE #11 – Soil
This soil was produced by weathering of specimens 5, 8 and 9. Can you see the black flaky mineral in this soil?________If so, what color is it now?______________Any color change is probably a result of chemical weathering. Now look carefully for the gray, glassy mineral (quartz), which was so prevalent in the rock sample. Can you recognize this mineral in the soil sample? **_(2 pts)_**

III. Erosion, transportation and deposition – Erosion, transportation and deposition of sediment at the Earth's surface occurs by running water, wind, ice or gravity induced movements. During transportation, the sediment is ABRADED, or worn down, producing smaller and more ROUNDED particles with increased transport distance. Also as a result of transportation and deposition, sedimentary material can be SORTED, or segregated primarily by size. Thus, a "well-sorted" sediment will contain material of nearly all the same size, while a "poorly sorted" sediment will contain material of broadly different grain sizes.

Listed below are three different types of sand from three distinctly different sedimentary environments: Eaton Canyon in the San Gabriel Mountains, the beach at Santa Monica, and a sand dune in Mexico. Briefly describe the rounding and sorting of each of these different sediments. **_(9 pts)_**

SAMPLE #	Rounding	Sorting	Environment
#12			
#13			
#14			

In the space below, please draw a sketch of several typical grains as they appear through the microscope. ***(3 pts)***

Sample #12 Sample #13 Sample #14

IV. Sedimentary Rocks - As sediments become buried and compacted, they turn into solid sedimentary rocks by the process of lithification. The most common means of lithification is cementation of the mineral grains by precipitation of mineral cement. This cement is different from matrix, which is smaller sedimentary material accumulated between larger sedimentary grains at the time of deposition.

SAMPLE #15 – Breccia
The cement in this rock was precipitated from groundwater circulation between the rock fragments. Describe the color size and shape of the rock fragments. ***(3 pts)***

Describe the color of the cement in the breccia. ***(2 pts)***

SAMPLE #16 – Conglomerate
This rock is a lithified gravel. What is the material between the pebbles?________________
Would you consider this matrix or cement? Why? ***(3 pts)***

SAMPLE #17 – Arkose Sandstone
Describe the degree of rounding and sorting of the grains in this rock. ***(2 pts)***

Was this sandstone deposited near to or far from the mountains from which this material was originally eroded? Why? ***(4 pts)***

SAMPLE #18 – Quartz sandstone
Describe the degree of rounding and sorting of the grains in this rock. ***(2 pts)***

Was this sandstone deposited near to or far from the mountains from which this material was originally eroded? Why? ***(4 pts)***

SAMPLE #19 – Shale
Notice the thin bedding (layering) of this sedimentary rock. What KIND of sediment do you suppose this rock was derived from? ***(2 pts)***

SAMPLE #20 – Rock Salt
Chemical sedimentary rocks are produced by direct precipitation of minerals from sea or lake water. Like igneous rocks, these rocks consist of interlocking mineral grains. However, the minerals involved are different: Halite (salt), gypsum, calcite, etc. In what important way is this sample of rock salt DIFFERENT from the plutonic igneous rocks you looked at earlier (e.g. samples 5 and 8)? ***(2 pts)***

V. Metamorphic rocks – If rocks are buried deeply, they are subjected to high temperatures and pressures (from the weight of the overlying rocks) and as result are changed into METAMORPHIC ROCKS.

SAMPLE #21 – Slate
This rock represents a slightly metamorphosed (low grade) version of shale (samples #19). How is this rock different from #19? ***(4 pts)***

SAMPLE #22 – Muscovite Schist
This rock was also originally a shale, but has been subject to a higher degree of metamorphism than the slate. Notice that the mineral grains are now large enough to see easily with your handlens or microscope. Do these grains show any preferred orientation?_________ Sketch them below. ***(2 pts)***

SAMPLE #23 – Biotite Gneiss
Describe the arrangement of minerals in this rock (A sketch may help). ***(3 pts)***

SAMPLE #24 – Augen Gneiss
This metamorphic rock was formed by deformation of a plutonic igneous rock, similar to sample #6. Compare the two rocks and describe how this rock differs from #6. The word AUGEN is German for “eye”; draw a sketch showing the “augen” in this rock. ***(4 pts)***

VI. Rock Cycle diagram. Revisit the diagram of the rock cycle on the first page of this lab. On the diagram, draw in any possible “shortcuts” to the complete cycle. Use arrowheads to denote which way things are going and label the shortcuts that you drew in. ***(2 pts)***